



# A directed artificial bee colony algorithm

Mustafa Servet Kiran<sup>a,\*</sup>, Oğuz Findik<sup>b</sup>

<sup>a</sup> Department of Computer Engineering, Faculty of Engineering, University of Selçuk, 42075 Konya, Turkey

<sup>b</sup> Department of Computer Engineering, Faculty of Engineering and Architecture, Abant İzzet Baysal University, 14280 Bolu, Turkey



## ARTICLE INFO

### Article history:

Received 23 May 2014

Received in revised form

11 September 2014

Accepted 9 October 2014

Available online 24 October 2014

### Keywords:

Swarm intelligence

Artificial bee colony

Direction information

Numerical optimization

## ABSTRACT

Artificial bee colony (ABC) algorithm has been introduced for solving numerical optimization problems, inspired collective behavior of honey bee colonies. ABC algorithm has three phases named as employed bee, onlooker bee and scout bee. In the model of ABC, only one design parameter of the optimization problem is updated by the artificial bees at the ABC phases by using interaction in the bees. This updating has caused the slow convergence to global or near global optimum for the algorithm. In order to accelerate convergence of the method, using a control parameter (modification rate-MR) has been proposed for ABC but this approach is based on updating more design parameters than one. In this study, we added directional information to ABC algorithms, instead of updating more design parameters than one. The performance of proposed approach was examined on well-known nine numerical benchmark functions and obtained results are compared with basic ABC and ABCs with MR. The experimental results show that the proposed approach is very effective method for solving numeric benchmark functions and successful in terms of solution quality, robustness and convergence to global optimum.

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## 1. Introduction

Swarm intelligence is a subfield of artificial intelligence and the algorithms of swarm intelligence have been developed by inspiring natural behavior of real ants [1], bees, birds, fishes [2], etc. Artificial bee colony algorithm is one of the swarm intelligence algorithms and has been developed by using waggle dance and foraging behaviors of real honey bee colonies [3]. In the nature, the honey bees search and forage food sources around the hive and share position information about the food sources. The honey bees which work in the foraging labor are divided into three groups. First group is employed bees and they move to hive nectar foraged from food source and position information about the food sources. Second group consists of onlooker bees and onlookers forage food sources by considering information shared by employed bees. The last group of the bees is scout bees. 5–10% of a bee population is scout bee [3,4] and scout bees search new food source around the hive and share position information of found new food sources with the other bees. For sharing information, the bees use waggle dance in the dance area of the hive and the time and glow of the dance depend on amount and distance from hive of food source.

Karaboga [3] used the aforementioned natural behaviors of the real honey bee in order to develop the artificial bee colony

algorithm and solve numerical optimization problems. In the ABC algorithm, half of the population is first scout bee. For each scout bee, a new food source which is possible solution for the optimization problem is generated. After generating new food source position, all the scout bees become employed bees and all employed bees try to improve food sources by using interaction between them. If a food source could not be improved in a certain time named as limit which is a control parameter for ABC algorithm, the employed bee of this food source becomes a scout bee. For this scout bee, a new food source is produced and the scout bee becomes employed bee, again. The onlooker bees wait to be shared food sources position by the employed bees in the hive. After employed bees share position information about the food sources, each onlooker bee select one of the food source position and tries to improve the food source position.

ABC algorithm is an iterative algorithm and only one design parameter of the optimization problem is updated by the each employed or onlooker bee at the each ABC iteration and updating only one design parameter has caused slow convergence for the algorithm. In order to overcome this issue, Akay and Karaboga [5] have proposed a control parameter called as modification rate-MR. In this work, we used directional information for each design parameter in order to cope slow convergence of the algorithm and the performance of the proposed approach is investigated on the well-known numerical benchmark optimization problems.

The paper is organized as follows: Section 1 introduces the study and gives literature review on artificial bee colony algorithm. The

\* Corresponding author. Tel.: +90 332 223 1992; fax: +90 332 223 2106.  
E-mail address: [mskiran@selcuk.edu.tr](mailto:mskiran@selcuk.edu.tr) (M.S. Kiran).

basic ABC algorithm and modifications are explained in Section 2 and the experiments and experimental results are presented in Section 3. The study is discussed in Section 4 and finally, the conclusions and future works are given in Section 5.

### 1.1. Literature review

The ABC algorithm was first introduced in 2005 and its performance is analyzed on three numerical problems [3]. It is mentioned that ABC algorithm has developed for solving numeric optimization problems [6] and proposed modifications and improvements for the methods have also been tested by using numeric problems. We give the literature review based on modifications and improvements of the method, and the studies on applications and hybridizations which use basic ABC algorithm can be found in a comprehensive literature review on ABC in [6]. The performance of ABC has been investigated on the numeric benchmark functions in [7–10]. Akay and Karaboga [5] introduced a modified version of ABC and used it for real-parameter optimization. In the modified ABC, Karaboga and Akay added two new control parameters named as modification rate-MR which is used for increasing convergence rate of ABC and scaling factor-SF which is used for controlling magnitude of perturbation to ABC. Dongli et al. [11] proposed three modified versions of ABC in order to obtain better quality results for the optimization problems. In the first modification, the neighborhood structure is changed in the solution updating equation of ABC, in the second modification, a new selection equation is proposed for onlooker bees in order to choose an employed bee and the last modified version of ABC is based on modification #1 and #2. Tsai et al. [12] proposed a model based on ABC, by employing Newtonian law of universal gravitation in onlooker bee phase of ABC. Alatas [13] proposed an ABC model that uses chaotic maps for parameter adaptation so as to prevent the ABC to get stuck local minimums. Zhu and Kwong [14] modified ABC algorithm (named as GABC) by appending the global best information of the population to exploitation equation of ABC in order to increase exploitation ability of ABC. Gao and Liu [15] modified search equation of the basic ABC by using chaotic systems and opposition-based learning methods and applied the modified ABC (called as MABC) to 28 benchmark functions. Banharnsakun et al. [16] improved the capability of convergence of ABC to a global optimum by using the best-so-far selection for onlooker bees and they tested performance of their method on the numerical benchmark functions and image registration. The Rosenbrock's rotational direction method which was designed to cope with specific features of "Rosenbrock's banana function" was applied to ABC in order to increase exploitation and local search abilities of the basic ABC [17]. Karaboga and Akay [18] adapted the basic ABC for constrained optimization problems by using the Deb's Rules and evaluated the performance of the adapted model on the 13 constrained optimizations in the literature. Kiran and Gündüz [19] proposed a crossover-based improvement for neighbor bee selection in onlooker bee phase of basic ABC algorithm. Hornig [20] proposed maximum entropy thresholding based on the ABC for image segmentation and Omkar et al. [21] presented vector evaluated ABC (VEABC) for multi-objective design optimization of laminated composite components and compared performance of VEABC with other population based methods. Liu et al. [22] have published a variant of ABC algorithm which is improved by using mutual learning which tunes the produced candidate food source with the higher fitness between two individuals selected by a mutual learning factor. Gao et al. [23] proposed two ABC-based algorithms which use two update rules of differential evolution (DE), and they are called as ABC/best/1 and ABC/best/2. The global best-based ABC methods also use chaotic initialization in order to properly distribute the agents to the search space, and the performance and accuracy of the methods are examined on

26 numerical benchmark functions [23]. Due to premature convergence and getting trap of local minima in ABC/best/1, Gao and Liu [24] proposed to use the update rule of ABC/best/1 algorithm for employed bees and the update rule of basic ABC for onlooker bees in order to reinforce exploration ability of the method, and they tested the variant of ABC on 28 numerical benchmark functions. In another study, Gao et al. [25] defined a new update rule for ABC algorithm, and the new update rule uses random solutions for obtaining the candidate solution. New update rule looks like to crossover operator of GA, and the method is named as CAB. In this study, the orthogonal learning strategy is proposed for ABC methods such as basic ABC (OABC), GABC (OGABC), CAB (OCABC), and their accuracies and performances are examined on numerical benchmark functions and compared with the other nature-inspired optimization algorithm.

Being analyzed literature review, it is seen that the update rule of ABC algorithm was modified, and the local search capability of the method is tried to improve in most of the papers which are based on improvement of the ABC algorithm. Therefore, we propose the same update rule with a bit modification in order to improve convergence characteristic of the basic ABC algorithm instead of local search capability. But it should be mentioned that this modification provides local search capability besides improvement convergence characteristics of the basic ABC algorithm.

## 2. ABC algorithm

By simulating intelligent behavior of real honey bee colonies, ABC algorithm tries to find a global optimum or near optimum solution for the optimization problems. In the ABC algorithm, number of food sources is equals to number of employed bees and also number of employed bees equals to number of onlooker bees. All the employed bees are scout bees in the starting of the algorithm and a food source position is produced for each scout bee using Eq. (1):

$$P_{ij} = X_j^{\min} + r \times (X_j^{\max} - X_j^{\min}), \quad i = 1, 2, \dots, NE \quad \text{and} \\ j = 1, 2, \dots, D \quad (1)$$

where  $P_{ij}$  is the  $j$ th dimension of  $i$ th food source which will be assigned to  $i$ th employed bee,  $X_j^{\min}$  and  $X_j^{\max}$  are the lower and upper bounds of the  $j$ th dimension, respectively,  $r$  is a random number between [0,1],  $NE$  is the number of employed bee and  $D$  is the dimensionality (the number of decision variables) of the problem or function optimized.

After producing a food source position for each scout bee, all the scout bees become employed bee. The qualities of the food sources of the employed bees are measured by using Eq. (2):

$$\text{fit}_i = \begin{cases} 1/(1 + f_i) & \text{if } (f_i \geq 0) \\ 1 + \text{abs}(f_i) & \text{if } (f_i < 0) \end{cases} \quad (2)$$

where  $\text{fit}_i$  is the fitness of the  $i$ th food source and  $f_i$  is the objective function value specific for the optimization problem. In addition, a trial counter is defined and reset for each food source and limit value for the population is described in the initialization of the algorithm.

The employed bees search around the self-food sources for new food sources. A new food source position around the food source of employed bee is obtained as follows:

$$V_{ij} = S_{ij} + \varphi \times (S_{ij} - N_j), \quad i=1, 2, \dots, NE, \quad k \in \{1, 2, \dots, NE\} \quad \text{and} \\ j \in \{1, 2, \dots, D\} \quad (3)$$

where  $V$  is the candidate food source position produced for food source position  $S$ ,  $N$  is the randomly selected neighbor food source for food source  $S$  and  $\varphi$  is a random number in range of  $[-1,1]$ . It is mentioned that only one dimension of the food source position

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